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Indian Standard

SPECIFICATION FOR LOW-VOLTAGE FUSES FOR VOLTAGES NOT EXCEEDING 1 000 V AC OR 1 500 V DC

PART 4 SUPPLEMENTARY REQUIREMENTS FOR FUSE LINKS FOR THE PROTECTION OF SEMICONDUCTOR DEVICES

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PART 4 SUPPLEMENTARY REQUIREMENTS FOR FUSE LINKS FOR THE PROTECTION OF SEMICONDUCTOR DEVICES

NATIONAL FOREWORD

This Indian Standard (Part 4) which is identical with IEC Pub 269-4 (1980), issued by the International Electrotechnical Commission (IEC) is being brought out to align the requirements for LV fuses with the corresponding requirements at the IEC level.

The text of the IEC Standard has been considered and approved by ET 39, Fuses Sectional Committee of BIS as suitable for publication as Indian Standard; superseding the contents of IS 9224 (Part 4) which covered requirements of LV fuses suitable for the protection of semiconductor devices.

CROSS REFERENCES

In this Indian Standard, the following International Standards are referred to. Read in their respective place the following:

International Standard (IEC)	*Indian Standard*
147-0 (1966)	IS 3700
269-1 (1868) 269-2A (1978) 269-3A (1978)	Now replaced by later versions at the IEC level identical with Part 1 of this standard
International Standard (ISO)	
3 (1973)	IS 1076

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EXPLANATORY NOTE

In view of the fact that this recommendation should be read together with IEC Publication 269-1, Low-voltage Fuses, Part 1: General Requirements, the numbering of its clauses and sub-clauses and tables is made to correspond to the latter.

1. General

Fuse-links for the protection of semiconductor devices shall comply with all requirements of IEC Publication 269-1, if not otherwise indicated hereinafter, and shall also comply with the supplementary requirements laid down below.

1.1 *Scope*

These supplementary requirements apply to fuse-links for application in equipment containing semiconductor devices for circuits up to 1 000 V a.c. or circuits of nominal voltages up to 1 500 V d.c. and also, in so far as they are applicable, for circuits of higher nominal voltages.

Notes 1. — Such fuse-links are commonly referred to as "semiconductor fuse-links".

2. — In most cases, a part of the associated equipment serves the purpose of a fuse-base. Owing to the great variety of equipment, no general rules can be given; the suitability of the associated equipment to serve as a fuse-base shall be subject to agreement between the manufacturer and the user. However, if separate fuse-bases or fuse-holders are used, they shall comply with the appropriate requirements of Part 1.

1.2 *Object*

The object of these supplementary requirements is to establish the characteristics of semiconductor fuse-links in such a way that they can be replaced by other fuse-links having the same characteristics provided that their dimensions are identical. For this purpose, they present in particular:

1.2.1 The characteristics of fuse-links with reference to:

a) their rated values: current, voltage, power loss;
b) their arc voltage limits;
c) their temperature rises in normal service;
d) their time/current characteristics;
e) their cut-off characteristics and their I^2t characteristics.

1.2.2 Type tests for verification of the characteristics of fuse-links.

1.2.3 The markings on fuse-links.

1.2.4 Availability and presentation of technical data.

2. Definitions

2.2 *General terms*

2.2.10 *Semiconductor device* (according to IEC Publication 147-0, Essential Ratings and Characteristics of Semiconductor Devices and General Principles of Measuring Methods, Part 0: General and Terminology).

A device whose essential characteristics are due to the flow of charge carriers within a semiconductor.

2.2.11 *Local air conditions*

The conditions of the micro-climate surrounding a fuse in an enclosure with other equipment.

Note. — The local air conditions include such factors as heat radiation and air motion.

2.2.12 *Semiconductor fuse-link*

A current-limiting fuse-link capable of breaking under specific conditions any current value not exceeding the rated breaking capacity which persists for a time sufficient to melt the fuse-element(s) (see Sub-clause 7.4.3).

3. Standard conditions for operation in service

3.2 *Temperature inside an enclosure*

Since the rated values of the fuse-links are based on specified conditions that do not always correspond to those prevailing at the point of installation, including the local air conditions, the user may have to consult the manufacturer concerning the possible need for re-rating.

3.5 *Voltage*

3.5.1 *Rated voltage*

For a.c., the rated voltage of a fuse-link is related to the applied voltage. It is based on the r.m.s. value of a sinusoidal a.c. voltage; it is further assumed that the applied voltage retains the same value throughout the operation of the fuse-link. All tests to verify the ratings are based on this assumption.

Note. — In many applications, the applied voltage will be sufficiently close to the sinusoidal form for the significant part of the operating time, but there are many cases where this condition is not satisfied.

The performance of a fuse-link subjected to a non-sinusoidal applied voltage can be evaluated by comparing, for the first approximation, the arithmetic mean values of the non-sinusoidal and sinusoidal applied voltages.

For d.c., the rated voltage of a fuse-link is related to the applied voltage. It is based on the mean value. When d.c. is obtained by rectifying a.c., the ripple is assumed not to cause a variation of more than 5% above or 9% below the mean value.

3.5.2 *Applied voltage in service*

Under service conditions, the applied voltage is that voltage which, in the fault circuit, causes the current to increase to such proportions that the fuse-link will operate.

For a.c., consequently, the value of the applied voltage in a single-phase a.c. circuit is usually identical to the power-frequency recovery voltage. For all cases other than the sinusoidal a.c. voltage, it is necessary to know the applied voltage as a function of time. For a unidirectional voltage, the important values are:

— the average value over the entire period of the operation of the fuse-link, and

— the instantaneous value near the end of the arcing period.

For d.c., the value of the applied voltage is usually approximately the same as the mean recovery voltage.

3.6 *Current*

The rated current of a semiconductor fuse-link is based on the r.m.s. value of a sinusoidal a.c. current at rated frequency.

For d.c., the r.m.s. value of current is assumed not to exceed the r.m.s. value based on a sinusoidal a.c. current at rated frequency.

Note. — The thermal response time of the fuse-element may be so short that is cannot be assumed that operation under conditions which deviate much from sinusoidal current can be estimated on the basis of the r.m.s. current alone. This is so, in particular, at lower frequency values and when the current presents salient peaks separated by appreciable intervals of insignificant current, for example in the case of frequency converters and traction applications.

3.7 *Frequency, power factor and time constant*

3.7.1 *Frequency*

The rated frequency refers to the frequency of the sinusoidal current and voltage that form the basis of the type tests.

Note. — In particular, where service frequency deviates significantly from rated frequency, the manufacturer should be consulted.

3.7.2 *Power factor*

The power factor is not lower than that shown in Table VIIIA of Part 1 appropriate to the value of prospective current.

3.7.3 *Time constant (τ)*

For d.c., the time constants expected in practice are considered to correspond to those in Table VIIIB.

Note. — Some service conditions may be found which exceed the specified performance shown in the table as regards time constant. In such a case a design of fuse-link which has been tested and marked accordingly should be used or the suitability of such a fuse-link be subject to agreement between the manufacturer and user.

3.9 *Breaking capacity*

For a.c., the rated breaking capacity is based on type tests performed in a circuit containing only linear impedance and with a constant sinusoidal applied voltage of rated frequency.

For d.c., the rated breaking capacity is based on type tests performed in a circuit containing only linear inductance and resistance with mean applied voltage.

Note. — The addition in practical applications of non-linear impedances and unidirectional voltage components may significantly influence the breaking severity either in a favourable or unfavourable direction.

5. **Characteristics of fuses**

5.1 *Summary of characteristics*

5.1.2 *For the fuse-link*

a) Rated voltage (see Sub-clause 5.2).
b) Rated current (see Sub-clause 5.3.2 of Part 1).
c) Kind of current or rated frequency (see Sub-clause 5.4).
d) Rated power loss (see Sub-clause 5.5).
e) Rated time/current characteristics (see Sub-clause 5.6.1).
f) Rated breaking capacity (see Sub-clause 5.7 of Part 1).
g) Cut-off characteristics (see Sub-clause 5.8.1).
h) I^2t characteristics (see Sub-clause 5.8.2).
i) Arc voltage limits (see Sub-clause 5.9).

5.2 *Rated voltage*

For rated voltages above 660 V, the values shall be selected from the R5 series or, where not possible, from the R10 series of ISO Recommendation R3.

Note. — For d.c., standard values of rated voltage are not specified.

5.4 *Rated frequency*

The rated frequency is that frequency to which the performance data are related.

5.5 *Rated power loss*

The rated power loss of a fuse-link is the value of power loss at the rated current of the fuse-link. The rated power loss is based on a local ambient air temperature of 20 °C to 25 °C and other conditions specified in Sub-clause 7.3.

The manufacturer shall, in addition, indicate the power loss as a function of current for a range of 50% to 100% of the rated current or for 50%, 63%, 80% and 100% of the rated current.

Note. — In cases where the resistance of the fuse-link is of interest, this resistance should be determined from the functional relation between the power loss and the associated value of current.

5.6 *Time/current characteristics, conventional currents and overload curves*

5.6.1 *Time/current characteristics*

The time/current characteristics of a fuse-link vary according to its design and also, for a given fuse-link, depend on the ambient temperature and the cooling conditions.

The manufacturer shall provide time/current characteristics based on an ambient temperature of 20 °C to 25 °C in accordance with the conditions specified in Sub-clause 8.3. The time/current characteristics of interest are the pre-arcing characteristic and operating characteristics having voltage as a parameter. The time/current characteristics are stated for rated frequency.

For d.c., they are stated for time constants according to Table VIIIB.

For some applications, and in particular for the higher values of prospective current (shorter times) the same information may be presented in the form of I^2t characteristics. It is recommended that in this region, I^2t characteristics shall be given as an alternative or in addition.

5.6.1.1 *Pre-arcing time/current characteristic*

For a.c., the pre-arcing time/current characteristic shall be based on a symmetrical a.c. current of a stated value of frequency (rated frequency).

Note. — This is of particular importance for the range of time between about 10 cycles of rated frequency and a time so short that the heating is truly adiabatic.

For d.c., the pre-arcing time/current characteristic is of particular significance for times exceeding 15 τ for the relevant circuit, and is identical to the a.c. pre-arcing time/current characteristic in this zone.

Notes 1. — Because of the wide range of circuit time constants likely to be experienced in service, the information for times shorter than 15 τ is conveniently expressed as a pre-arcing I^2t characteristic.

2. — The value of 15 τ has been chosen to avoid the effects which different rates of rise of current have on the pre-arcing time/current characteristic at shorter times.

5.6.1.2 *Operating time/current characteristics*

The operating time/current characteristics shall be given with applied voltage as a parameter and for a stated power factor value. In principle, they shall be based on the moment of current initiation that leads to the highest operating I^2t value (see Sub-clause 8.7). The voltage parameters shall include at least 100%, 50% and 25% of rated voltage.

For d.c., the operating time/current characteristics are not applicable because they are not significant for times in excess of 15 τ (see Sub-clause 5.6.1.1).

5.6.3 *Overload curves for semiconductor fuse-links*

5.6.3.1 *Verified overload capability*

The manufacturer shall indicate sets of co-ordinate points along the time/current characteristic (see Sub-clause 5.6.1) for which the overload capability has been verified in accordance with the procedure indicated in Sub-clause 8.4.3.4.

The number and the location of the sets of co-ordinate points for which the overload capability shall be verified are to be selected at the discretion of the manufacturer. The time co-ordinates for the verification of the overload capability shall be selected within the range of 0.01 s to 60 s. Further sets of the co-ordinate points may be added according to agreement between manufacturer and user.

5.6.3.2 *Conventional overload curve*

The conventional overload curve is formed of straight-line sections emanating from the co-ordinate points of verified overload capability. From each set of co-ordinate points, two lines are drawn:

- — one from the verified point and following points of constant values of current towards shorter times;
- — the other from the verified point and following points of constant values of I^2t towards longer times.

These line sections, ending at the line representing rated current, form the conventional overload curve (see Figure 1, page 43).

Note. — For practical applications, a few points of verified overload capability are sufficient. As the number of points of verified overload capability increases, the conventional overload curve becomes more precise.

5.8 *Cut-off and I^2t characteristics*

5.8.1 *Cut-off characteristics*

The manufacturer shall provide the cut-off characteristics which shall be given according to the example shown in Figure 2 of Part 1 in a double logarithmic presentation with the prospective current as abcissa and if necessary with applied voltage as a parameter.

For a.c., the cut-off characteristics shall represent the highest values of current likely to be experienced in service. They shall refer to the conditions corresponding to the test conditions of this standard, for example given voltage, frequency and power-factor values. The cut-off characteristics are verified by the tests specified in Sub-clause 8.6.

For d.c., the cut-off characteristics shall represent the highest values of current likely to be experienced in service in circuits having a time constant of 15 ms to 20 ms. These values will be exceeded in circuits of smaller time constants. The manufacturer shall provide the relevant information to enable the determination of these higher cut-off characteristics.

Note. — The cut-off characteristic varies with the circuit time constant. The manufacturer shall provide the relevant information to enable these variations to be determined at least for time constants of 5 ms and 10 ms.

5.8.2 I^2t *characteristics*

5.8.2.1 *Pre-arcing* I^2t *characteristic*

For a.c., the pre-arcing I^2t characteristic shall be based on a symmetrical a.c. current at a stated frequency value (rated frequency).

For d.c., the pre-arcing I^2t characteristics shall be based on r.m.s. d.c. current at a time constant of 15 ms to 20 ms.

Note. — For certain fuses the pre-arcing of I^2t characteristic varies with circuit time constant. The manufacturer shall provide the relevant information to enable these variations to be determined at least for time constants of 5 ms and 10 ms.

5.8.2.2 *Operating* I^2t *characteristics*

For a.c., the operating I^2t characteristics shall be given with applied voltage as a parameter and for a stated power-factor value. In principle, they shall be based on that moment of current initiation that leads to the highest operating I^2t value (see Sub-clause 8.7). The voltage parameters shall include at least 100%, 50% and 25% of rated voltage.

For d.c., the operating I^2t characteristics shall be given with the applied voltage as a parameter and for a time constant of 15 ms to 20 ms. The voltage parameters shall include at least 100% and 50% rated voltage. It is permitted to determine the operating I^2t characteristics at the lower voltages from tests in accordance with Table VIIIB.

5.9 *Arc voltage characteristics*

Arc voltage characteristics provided by the manufacturer shall give the highest (peak) value of arc voltage as a function of the applied voltage of the circuit in which the fuse-link is inserted and, in the case of a.c., for power factors as stated in Table VIIIC and, in the case of d.c., at time constants of 15 ms to 20 ms.

6. Markings

6.2 *Markings on fuse-links*

- Name of the manufacturer or trade mark by which he may be readily identified.
- Catalogue number or type designation in sufficient detail to make it possible to obtain all relevant information from the manufacturer.

Note. — It is customary to indicate as an additional marking rated voltage and rated current.

7. Standard conditions for construction

7.3 *Temperature rise and power loss*

Fuse-links shall be so designed and proportioned as to carry, when tested in accordance with Sub-clause 8.3, the rated current without exceeding:

- the temperature-rise limit of the hottest upper metal part of the fuse-link indicated by the manufacturer or otherwise specified (see Figure 2, page 44);

- the power loss at rated current indicated by the manufacturer.

7.4 *Operation*

7.4.3 *Semiconductor fuse-links*

The fuse-link shall be so designed as to carry continuously any value of current up to its rated current (see Sub-clause 8.4.3.5).

The fuse-link shall operate and break the current for any current value not exceeding the rated breaking capacity which persists for a time sufficient to melt the fuse-element(s) but not exceeding 30 s.

Notes 1. — By agreement between manufacturer and user, shorter times may be chosen for special applications.

2. — Semiconductor fuse-links intended to give additional protection against overload shall also comply with the relevant requirements for general purpose fuse-links.

7.5 *Breaking capacity*

A fuse-link shall be capable of breaking, at a voltage not exceeding the voltage specified in Sub-clause 8.5, any circuit having a prospective current between the current which causes melting of the fuse-element(s) in a time corresponding to Sub-clause 7.4.3 and the rated breaking capacity

- for a.c.: at power factors not lower than those in Table VIIIA appropriate to the value of the prospective current;
- for d.c.: at time constants not greater than 15 ms to 20 ms appropriate to the value of the prospective current.

7.6 *Cut-off characteristics*

The values of cut-off currents measured as specified in Sub-clause 8.6 shall not exceed the values stated by the manufacturer (see Sub-clause 5.8.1).

7.7 *I^2t characteristics*

The values of operating I^2t determined as described in Sub-clause 8.7 shall not exceed those stated by the manufacturer. The values of pre-arcing I^2t determined as described in Sub-clause 8.7 shall be not less than the values stated (see Sub-clauses 5.8.2.1 and 5.8.2.2).

7.12 *Arc voltage characteristics*

The arc voltage values, measured as described in Sub-clause 8.7.3, shall not exceed those stated by the manufacturer (see Sub-clause 5.9).

7.13 *Special operating conditions*

Special operating conditions, such as high value of gravitational force, shall be subject to agreement between manufacturer and user.

8. Tests

8.1 *General*

8.1.4 *Arrangement of the fuse-link*

The fuse-link shall be mounted open in surroundings free from draughts and, unless otherwise specified, in a vertical position (see Sub-clause 8.3.1 and Figure 2, page 44).

8.1.5 *Testing of fuse-links*

8.1.5.1 *Type tests*

The type tests on fuse-links are listed in Table IVA. The internal resistance of all fuse-links shall be determined and recorded in the test report(s).

TABLE IVA

List of complete tests on semiconductor fuse-links

Test according to sub-clause	Number of fuse-links to be tested
8.3 Temperature rise and power loss	1
8.4.3.5 Verification of rated current	1
For a.c.:	
8.5 No. 2a Breaking capacity[1]	1
No. 2 Breaking capacity[1]	3
No. 1 Breaking capacity[1]	3
8.6 No. 10 Operating characteristics tests[2]	2
No. 9 Operating characteristics tests[2]	2
No. 8 Operating characteristics test[2]	2
No. 7 Operating characteristics test[2]	2
No. 6 Operating characteristics test[2]	2
8.4.3.4 Verification of overload capability[3]	1
For d.c.:	
8.5 No. 12a Breaking capacity and operating characteristics	1
No. 12 Breaking capacity and operating characteristics	3
No. 11 Breaking capacity and operating characteristics	3

[1] Valid also for pre-arcing characteristics if ambient air temperature is between 20 °C and 25 °C.

[2] The tests are valid for cut-off, I^2t arc voltage and pre-arcing characteristics.

[3] The number of points at which the overload capability is verified should be at the manufacturer's discretion.

8.1.5.2 *Type test exemptions for fuse-links of a homogeneous series*

Fuse-links having intermediate values of rated current in a homogeneous series are exempted from type tests if the fuse-link of the largest rated current has been tested to the requirements of Sub-clause 8.1.5.1 and if the fuse-link of the smallest rated current has been submitted to the tests indicated in Table IVB.

Note. — The conditions of the homogeneous series for semiconductor fuse-links are still under consideration.

TABLE IVB

Tests on semiconductor fuse-links of the smallest rated current of a homogeneous series

Tests according to sub-clause	Number of fuse-links to be tested
8.3 Temperature rise and power loss	1
For a.c:	
8.6.2 No. 6 Operating characteristics tests	2
For d.c.:	
8.6.2 No. 11 Operating characteristics test	3

The values of test current are specified in Table VIIIB.

8.3 *Verification of temperature-rise limits and power loss*

8.3.1 *Arrangement of the fuse-link*

Only one fuse-link shall be used for the test. The fuse-link shall be mounted vertically in the conventional test arrangement shown in Figure 2, page 44.

The current density of the copper conductors forming part of the conventional test arrangement shall be not less than 1 A/mm^2 and not more than 1.6 A/mm^2, these values being based on the rated current of the fuse-link. The ratio of width to thickness of these conductors shall not exceed

10 for current ratings less than 200 A;
5 for current ratings 200 A and above.

The ambient air temperature during this test shall be between + 10 °C and + 30 °C.

When conducting the temperature-rise tests, the cross-sectional areas of the conductors connecting the conventional test arrangement to the supply are of importance. The cross-sectional area shall be selected in accordance with Table VI of Part 1, excluding Note 1, and the conductors shall be at least 1 m long.

For fuse-links intended to be used in separate fuse-bases, the test may be performed in these fuse-bases with conductors according to Table VI of Part 1; in other cases, the test shall be performed in the manner described in these requirements.

For special fuse-links or special applications that cannot be accommodated in the conventional test arrangement, or for which this test arrangement is not applicable, special tests shall be performed according to the manufacturer's instructions and all pertinent data shall be recorded in the test report.

8.3.4 *Test method*

8.3.4.1 and 8.3.4.2 *Temperature rise and power loss*

The power loss test shall be made successively at least at 50% and at 100% of rated current at rated frequency. It is permissible to make the test at any value of voltage.

8.3.4.3 *Test duration*

The test shall be continued at each value of current until steady state is reached but without exceeding the conventional time specified in Table VII of Part 1.

8.3.5 *Acceptability of test results*

The temperature rise and the power loss of the fuse-link shall not exceed the values specified by the manufacturer.

After the tests, the fuse-link shall not have significantly changed its characteristics.

Note. — A measurement of the resistance (see Sub-clause 8.1.5.1) before and after the test gives an indication of conformity with these requirements.

8.4 *Verification of operation*

8.4.1 *Arrangement of fuse-link*

The arrangement of the fuse-link for the verification of operation shall be as described in Sub-clauses 8.1.4 and 8.3.1.

8.4.3 *Test method and acceptability of test results*

8.4.3.1 *Time/current characteristics*

As far as applicable, the time/current characteristics given by the manufacturer may be verified on the basis of the results obtained from the oscillographic records taken during the performance of the tests, according to Sub-clauses 8.5, 8.6 and 8.7.

From the relevant oscillograms, the values of the actual pre-arcing time shall be determined from the instant of closing the circuit until the instant when the voltage measurement shows the beginning of the arc and shall be expressed in the form of virtual time. The actual operating time shall be determined from the instant of closing the circuit until the circuit is definitely broken and shall be expressed in the form of virtual time.

For a.c., prospective currents leading to actual pre-arcing time values of less than ten cycles of rated frequency and up to current values where the melting is adiabatic, the current shall be initiated in such a manner that the prospective current will be symmetrical.

For d.c., the time/current characteristics determined for a.c. are applicable for times longer than 15 τ for the relevant circuit.

When for the fuse-links of a homogeneous series (see Sub-clause 8.1.5.2) the complete test according to Sub-clause 8.5 is made only on the fuse-link having the largest rated current, it shall be sufficient to verify only the pre-arcing time for the fuse-link having the smallest rated current.

Pre-arcing time/current characteristics can be determined at any convenient voltage value and on any linear circuit. Tests to determine operating time/current characteristics require the proper voltage values and circuit characteristics.

8.4.3.2 *Operation of indicating devices and strikers, if any*

The characteristics and verification of characteristics of indicating devices or strikers shall be subject to agreement between manufacturer and user.

8.4.3.4 *Verification of overload capability*

One fuse-link is tested under the same test conditions as indicated in Sub-clause 8.3.1.

It is subjected to 100 load cycles, each cycle having a total duration of 0.2 times the conventional time, the "on" period with a current value and a duration corresponding to the co-ordinates of the overload capability to be verified, the "off" period forming the rest of the cycle. The conventional time is that specified for general-purpose fuse-links in Table VII of Part 1.

After this test, the fuse-link shall not have significantly changed its characteristics (see Sub-clause 8.3.5).

Note. — These tests are deemed to verify the overload capability of the fuse on d.c. for pre-arcing times greater than 15 τ for the relevant circuit.

8.4.3.5 *Verification of rated current*

The fuse-link is tested under the same test conditions as indicated in Sub-clause 8.3.1.

It is subjected to 100 test cycles, each consisting of an "on" period of 0.1 times the conventional time as specified in Table VII of Part 1 at rated current and an "off" period of the same duration. After this test, the fuse-link shall not have changed its characteristics (see Sub-clause 8.3.5).

Note. — A measurement of the resistance (see Sub-clause 8.1.5.1) before and after the test gives an indication of conformity with these test conditions.

8.5 *Verification of the breaking capacity*

8.5.1 *Arrangement of the fuse*

In addition to the conditions of Sub-clauses 8.1.4 and 8.3.1, the following applies:

For breaking tests, the fuse-link shall be mounted in a manner resembling its practical use, in particular with respect to the location of the conductors. In cases where the fuse-link can be used rigidly supported at one end only, it shall be so mounted for the test. Fuse-links intended to be always rigidly supported at both ends shall be so tested.

8.5.3 *Measuring instruments*

Sub-clause 8.5.3 of Part 1 applies and is completed by the following note:

Note. — The determination of I^2t characteristics, arc voltage and cut-off current is very critical and special measuring techniques are necessary.

8.5.5 *Test method*

8.5.5.1 In order to verify that the fuse-link satisfies the conditions of Sub-clause 7.5, tests No. 1 to No. 2a as described below shall be made—unless otherwise specified—with the values stated in Table VIIIA (see Sub-clause 8.5.2) for each of these tests.

Tests No. 1 and No. 2

For each of these tests, three fuse-links shall be tested in succession.

If, during test No. 1, the requirements of test No. 2 are met on one or more tests, then these tests need not be repeated as part of test No. 2.

Test No. 2a for a.c. and test No. 12a for d.c.

For a.c., the values of test current are specified in Table VIIIA. For d.c., the values of test current are specified in Table VIIIB. For a.c. tests, the closing of the circuit in relation to the passage of the applied voltage through zero may be effected at any instant.

8.5.5.2 For one of the tests No. 2 and for test No. 2a, the recovery voltage shall be maintained at a value of $100\%\,^{+15\%}_{-0\%}$ of the rated voltage for at least:

— 30 s after the operation for fuse-links not containing organic material;

— 5 min after the operation in all other cases.

Switching over to another source of supply is permitted after 15 s if the switching time (interval without voltage) does not exceed 0.1 s.

For all other tests the recovery voltage shall be maintained at the same value for 15 s after the operation of the fuse.

TABLE VIIIA

Values for breaking-capacity tests for a.c.

	Tests according to Sub-clause 8.5.5.1		
	No. 1	No. 2	No. 2a
Power frequency recovery voltage**	110% of the rated voltage $^{+5\%*}_{-0\%}$		
Prospective test current	I_1	I_2	I_{2a}
Tolerance on current	$^{+10\%}_{-0\%}$	Not applicable	
Power factor	Where I_1 is equal to or less than 20 kA: 0.2 to 0.3 Where I_1 is greater than 20 kA: 0.1 to 0.2		0.3 to 0.5
Making angle after voltage zero	Not applicable	$0\ ^{+20°}_{-0°}$	Not specified
Initiation of arcing after voltage zero	65° to 90°	Not applicable	

* The positive tolerance may be exceeded with the manufacturer's consent.

** For single-phase circuits, the r.m.s. value of the applied voltage is for all practical purposes equal to the r.m.s. value of the power frequency recovery voltage.

I_1 = current which is used in the designation of the rated breaking capacity

I_2 = current which shall be chosen in such a manner that the test is made at conditions which approximate those giving maximum arc energy

Note. — The condition may be deemed to be satisfied if the current at the beginning of arcing (instantaneous value) has reached a value between $0.6\sqrt{2}$ and $0.75\sqrt{2}$ times the prospective current (r.m.s. value of the a.c. component).

As a guide for practical application, the value of current I_2 may be found between three and four times the current which corresponds to a pre-arcing time of one half-cycle of rated frequency on the time/current characteristic.

I_{2a} = current which leads to a pre-arcing time of 1 to 1.5 times the value corresponding to Sub-clause 7.4.3, except that, with the manufacturer's consent, the upper limit may be exceeded

8.5.8 *Acceptability of test results*

Fuse-links shall be deemed not to comply with this standard if, during the tests, one or more of the following failures occur:

— ignition of the fuse-link excluding any paper labels or the like used as indicating devices;

— mechanical damage to the conventional test arrangement;
— mechanical damage to the fuse-link;

Note. — Thermal cracking which leaves the fuse-link in one piece is accepted.

— burning or melting through of end caps;
— significant movement of end caps.

TABLE VIIIB

Values for breaking capacity tests and for verification of cut-off, I^2t and arcing voltage characteristics for d.c.

	Tests according to Sub-clause 8.5.5.1		
	No. 11	No. 12	No. 12a
Mean value of recovery voltage	110% of the rated voltage $^{+5\%*}_{-0\%}$		
Prospective test current	I_1	I_2	I_{2a}
Tolerance on current	+10% −0%	Not applicable	
Time constant**	15 ms to 20 ms		

* With the manufacturer's consent, the upper limit may be exceeded.

** In some practical applications, time constant values may be found which are shorter than those indicated in the tests, this may result in a more favourable fuse performance. Time constants which are considerably longer than those indicated will in most cases significantly affect the performance of the fuse-link, in particular with respect to the rated voltage. For such applications, further information may be available from the manufacturer.

I_1 = current which is used in the designation of the rated breaking capacity (see Sub-clause 5.7)

I_2 = current which shall be chosen in such a manner that the test is made under conditions which approximate to those giving maximum arc energy

Note. — This condition may be deemed to be satisfied if the current at the beginning of arcing has reached a value between 0.5 and 0.8 times the prospective current.

I_{2a} = current which leads to a pre-arcing time of 1 to 1.5 times the value corresponding to Sub-clause 7.4.3, except that, with the manufacturer's consent, the upper limit may be exceeded

8.6 *Verification of cut-off characteristics*

8.6.1 *Test method*

The test arrangement, test circuit, measuring instruments, calibration of test circuit and interpretation of oscillograms shall be as for the breaking capacity tests. These tests may be used to prove the characteristics of all fuse-links of a homogeneous series.

For a.c., tests shall be made as specified in Table VIIIC. For each of the tests Nos. 6 to 10, two fuse-links of the maximum current rating of a homogeneous series shall be tested. In addition, test duty No. 6 shall be performed on two fuse-links of the minimum current rating of a homogeneous series. If, during test No. 6, the requirements of test No. 7 are met on one or more tests, then these tests are deemed to fulfil test No. 7.

TABLE VIIIC

Values for verification of cut-off, I^2t and arc voltage characteristics for a.c.

	Tests according to Sub-clauses 8.6 and 8.7				
	No. 6	No. 7	No. 8	No. 9	No. 10
Power-frequency recovery voltage as a percentage of a rated voltage**	100%*			50%*	25%*
Prospective test current	I_1	I_2	I_6	I_7	I_8
Tolerance on current	±10%	Not applicable	±30%	Not applicable	
Power factor	Where I_1 is equal to or less than 20 kA: 0.2 to 0.3*** Where I_1 is greater than 20 kA: 0.1 to 0.2				
Making angle after voltage zero	Not applicable	$0 \begin{smallmatrix} +20^\circ \\ -0^\circ \end{smallmatrix}$	Not applicable		
Initiation of arcing after voltage zero	65° to 90°	Not applicable	65° to 90°		

* A tolerance of ±5% of the value of the power-frequency voltage is admitted. The positive tolerance may be exceeded with the manufacturer's consent.

** For single-phase circuits, the r.m.s. value of the applied voltage is for all practical purposes equal to the r.m.s. value of the power-frequency recovery voltage.

*** Power factor values lower than those indicated for the test may be found in some practical applications, but it is considered that this does not significantly influence the performance of the fuse. However, a power factor value appreciably higher than that of the test circuit may result in a more favourable performance, in particular with respect to the I^2t values for breaking. For such applications, further information may be available from the manufacturer.

I_1 = current which is used in the designation of the rated breaking capacity (see Sub-clause 5.7 of Part 1)
I_2 = current which shall be chosen in such a manner that the test is made under conditions which approximate those giving maximum arc energy
I_6 = the geometric mean value of I_1 and I_2
I_7 = 0.5 I_1 to I_1
I_8 = 0.25 I_1 to I_1

Note. — Tests Nos. 6, 7 and 8 are to establish the characteristics at rated voltage. Tests Nos. 9 and 10 provide the basis for the characteristics at lower voltages.

For d.c., tests shall be made as specified in Table VIIIB. Tests conducted in accordance with Sub-clause 8.5 shall be used for evaluation according to Sub-clause 8.6.2.

8.6.2 *Verification of cut-off characteristics and acceptability of test results*

For a.c., the values of peak current shall not exceed those indicated by the manufacturer for the stated applied voltages. The cut-off characteristics shall be verified from tests Nos. 6, 7 and 8 and for lower voltages from tests Nos. 9 and 10.

For d.c., cut-off characteristics shall be verified from tests Nos. 11, 12 and 12a of Table VIIIB.

8.7 *Verification of the I^2t characteristics and arc voltage characteristics*

8.7.1 *Test method*

The test method is that specified in Sub-clause 8.6.1.

8.7.2 *Verification of I^2t characteristics and acceptability of test results*

For a.c., the I^2t characteristics shall be verified from tests Nos. 6, 7 and 8 according to Table VIIIC and for lower voltages from tests Nos. 9 and 10. I^2t values shall be determined from the appropriate oscillograms.

For d.c., the I^2t characteristics shall be verified from tests Nos. 11, 12 and 12a according to Table VIIIB.

The values of the pre-arcing I^2t at each prospective current shall be not less than the values stated by the manufacturer.

The values of operating I^2t at each prospective current shall not exceed the values indicated by the manufacturer for the stated applied voltage.

8.7.3 *Verification of arc voltage characteristics and acceptability of test results*

The highest values of arc voltage derived from each of the following tests shall not exceed those indicated by the manufacturer.

For a.c., arc voltage characteristics shall be verified from all tests in Tables VIIIA and VIIIC. If, on test No. 7, the arc voltage obtained is appreciably in excess of that obtained on test No. 6, further tests at the current I_2 shall be performed at 50% and at 25% of the rated voltage to determine the maximum arc voltage at these lower voltages.

For d.c., the arc voltage characteristics shall be verified from all tests in Table VIIIB.

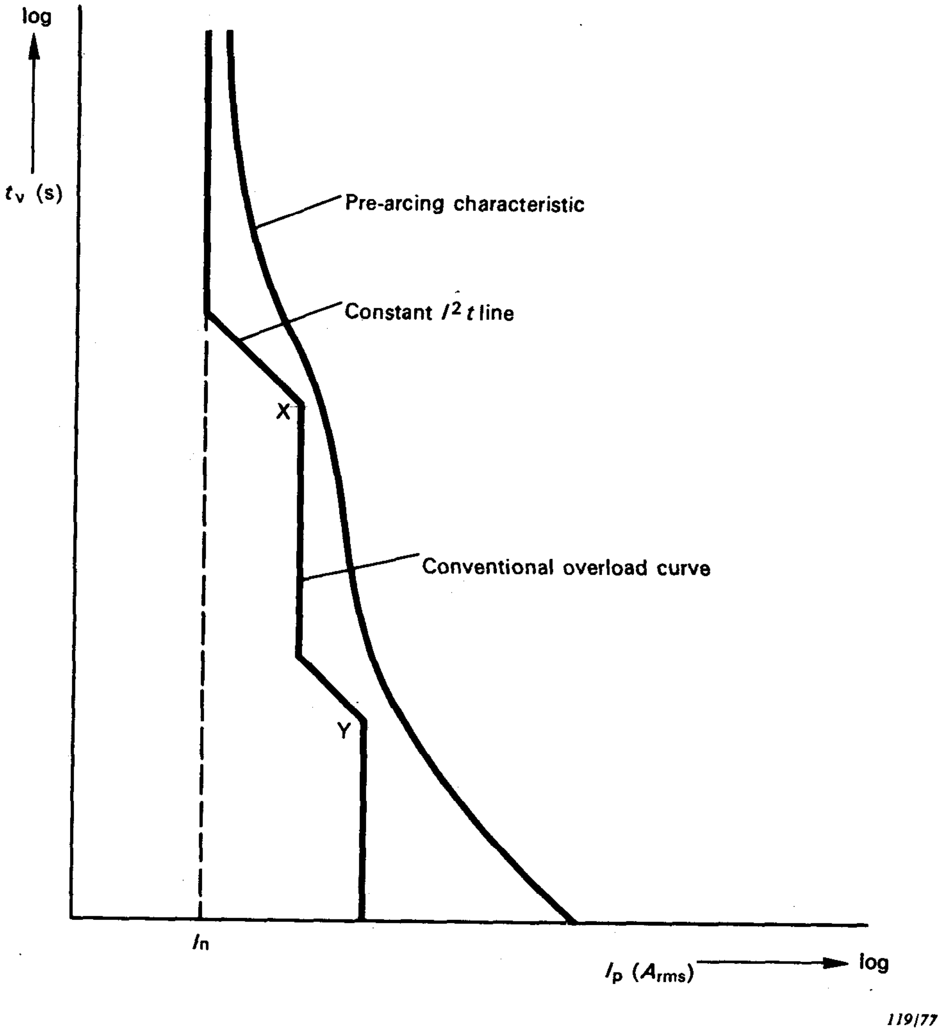
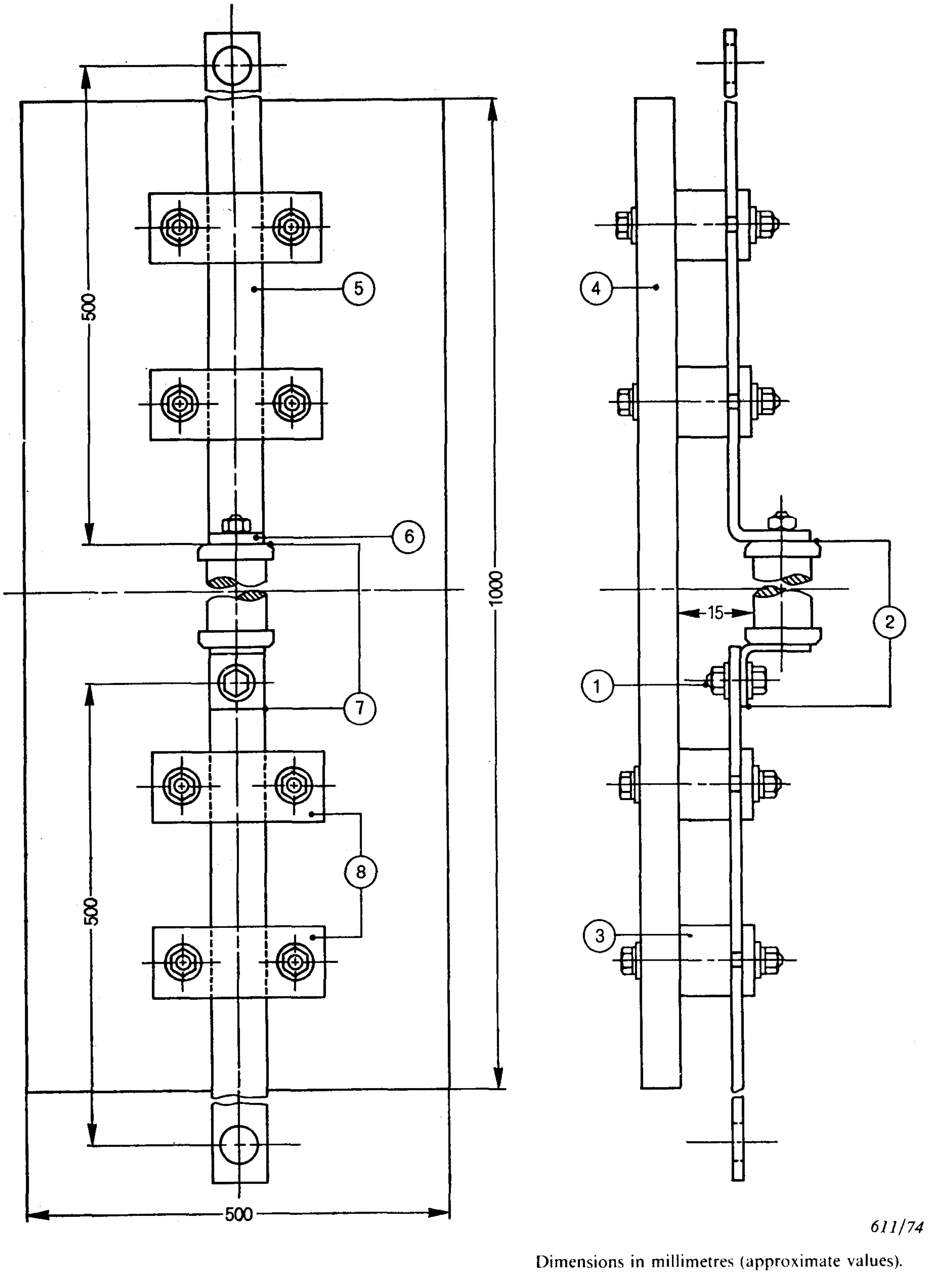


FIG. 1. — Conventional overload curve (example) (X and Y are points of verified overload capability).



Dimensions in millimetres (approximate values).

(For notes, see facing page)

FIG. 2. — Conventional test arrangement.

Notes for Figure 2:

1. Fixing bolts.
2. Alternative points of measurement of voltage for determination of power loss.
3. Insulating blocks (for example, wood).
4. Insulated base panel (for example, 16 mm plywood).

5. Matt black finish.
6. Position of thermocouple fixed to hottest upper metal part of the fuse-link indicated by the manufacturer or otherwise specified.

7. Contact surface to be tin-plated.
8. Insulated clamps. Where necessary, the two upper clamps may be left loose.

APPENDIX A

GUIDE FOR THE CO-ORDINATION OF FUSE-LINKS WITH SEMICONDUCTOR DEVICES

(The numbering of the following clauses and sub-clauses is not related to that of the requirements in the main text)

A1. **General**

A1.1 *Scope*

This guide is limited to the use of fuse-links in circuits having the characteristics generally found in converters based on semiconductors.

It deals with the performance of fuse-links under the conditions covered, but it does not deal with the adequacy of fuse-links with respect to converters.

Note. — Particular attention is directed to the fact that fuse-links intended for use on a.c. are not necessarily suitable for use on d.c. The manufacturer should be consulted on all cases of d.c. applications. It should be noted in particular that the relationship between rated voltage a.c. versus rated voltage d.c. cannot be stated in a general form. The few references in this guide to d.c. operations are not complete and do not cover all of the important factors related to such use.

A1.2 *Object*

It is the object of this guide to explain the performance to be expected from the fuse-links in terms of their ratings and in terms of the characteristics of the circuits of which they form a part, in such a manner that this may form the basis for the selection of the fuse-links.

A2. **Definitions** (see also the definitions of Clause 2)

Pulsed current (in a semiconductor fuse-link)

A unidirectional current the instantaneous value of which varies in a cyclic manner and includes intervals of zero or insignificantly small values of current for times significant in relation to the total cycle.

Note. — A typical pulsed current is the current in a single arm of a bridge-connected rectifier.

Pulsed load (in a semiconductor fuse-link)

A load where the r.m.s. value of the current varies in a cyclic manner and includes intervals of zero current or insignificantly small values of current for times significant in relation to the total load cycle.

Note. — In a rectifier circuit, a pulsed load may be caused by cyclic, making and breaking of the d.c. circuit current, for instance by the starting and stopping of a motor.

A3. Current-carrying capabilities

A3.1 *Rated current*

The rated current of a semiconductor fuse-link is assigned by the manufacturer and verified in particular by the temperature-rise test (see Sub-clause 8.3) and by the repetitive duty test as described in Sub-clause 8.4.3.5.

Note. — The ability to carry current without deterioration is closely related to the temperature variations. The data given by the manufacturer relate to the test conditions (see Sub-clauses 8.1.4 and 8.3). The cooling conditions depend on the physical properties of the fuse-link, the flow of the cooling medium, the type and temperature of the connections and of adjacent hot bodies.

Guidance on the influence of these factors may be obtained from the manufacturer.

A3.2 *Continuous duty current*

For most kinds of fuse-links for semiconductor devices, the continuous duty current is identical with the rated current (see Sub-clause A3.1). However, fuse-links designed for applications not requiring the carrying of rated current continuously are to be de-rated for continuous duty.

A3.3 *Repetitive duty current*

The tests for rated current verify that the fuse-link is able to withstand, under the test conditions, repetition of the rated current load at least 100 times. The expected life in number of repetitions will increase as the value of the actual load current is reduced in relation to the rated current.

The manufacturer's advice should be sought on the suitability of a given fuse-link for a required repetitive duty, since the specified tests establish minimum life expectancy requirements only.

A3.4 *Overload current*

The overload capability (see Sub-clause 5.6.3.1) indicated by the manufacturer is based on one or more co-ordinates of time and current for which the overload capability has been verified under conditions identical with those indicated for the rated current (see Sub-clause 8.4.3.4). The conventional overload characteristic based on these verified points is a conservative estimate of the overload capability (see Sub-clause 5.6.3.2 and Figure 1, page 43).

As the actual overload rarely shows the same function of time as the conventional overload, it has to be transformed into an equivalent conventional one as follows:

- the maximum value of the actual overload is equated to the maximum value of an equivalent conventional overload;
- the duration of the equivalent conventional overload shall be such that its I^2t becomes equal to the I^2t of the actual load integrated over a time of 0.2 times the conventional time of the fuse-link.

Any value of load which approaches 0.2 times the conventional time shall be considered to be a continuous load with respect to the fuse-link.

However, as the verification of the overload capability is based on 100 overload cycles, the practical cases of repetitive overload may necessitate a de-rating. The manufacturer's advice should be sought.

A3.5 *Peak current* (cut-off current)

The highest value of peak current is obtained when the fuse-link operates under adiabatic conditions.

Under conditions where the rate-of-rise of the current is essentially constant, the instantaneous value of the current reached at the end of the pre-arcing period increases as the cube root of the rate-of-rise. For many fuse-links, this is essentially the peak value. For fuse-links reaching the peak value of current significantly later (in the arcing period), no general statement can be made and information should be obtained from the manufacturer.

A4. Voltage characteristics

A4.1 *Rated voltage*

The rated voltage (see Sub-clause 5.2) of the fuse-link for the protection of semiconductor devices is a value of sinusoidal applied voltage of rated frequency (or, in some cases, d.c.) assigned by the manufacturer. Information on the fuse-link is related to the rated voltage. Comparison between fuse-links of different manufacture on the basis of the voltage rating alone is insufficient.

A4.2 *Applied voltage in service*

The applied voltage is the voltage in the fault circuit that causes the fault current to flow. In most cases it is possible to consider the no-load voltage in the fault circuit as the applied voltage, since the influence of the voltage drop can usually be disregarded.

Note. — The applied voltage may be affected by any commutation which takes place during the operation of the fuse-link or by the arc voltage of another fuse-link.

During the *pre-arcing period*, the applied voltage and the self-inductance of the circuit determine the rate-of-rise of the fault current (in general, its increase from zero to almost its peak value). In a given circuit, i.e. for a given self-inductance, it is the value of I^2t that determines the end of the pre-arcing period, and it is the integral of the applied voltage during that period that determines the instantaneous value of the current reached by the end of the pre-arcing period.

During the *arcing period*, the difference between the arc voltage and the applied voltage determines the rate-of-change of the current. Generally, it is a decrease from the peak value to zero. The zero value is reached in that instant where the integral of this difference becomes equal to the integral of the applied voltage over the pre-arcing period. For the time in which the arc voltage is less than the applied voltage, the current continues to increase, but in most cases this time is short and the associated current increase negligible.

For the fuse-link operating in the *adiabatic*, or *near adiabatic zone*, the pre-arcing I^2t is a well-defined quantity. The arcing I^2t can assume very different values, even for the same arcing time. It becomes a minimum when the excess arc voltage reaches its maximum during the early part of the arcing period.

A4.3 *Arc voltage*

The peak value of the arc voltage indicated by the manufacturer is that obtained under the most unfavourable conditions. The arc voltage characteristic is given as a function of the applied voltage. The peak value of the arc voltage should be limited to that which can be withstood by the semiconductor device.

A5. **Power loss characteristics**

A5.1 *Rated power loss*

The rated power loss is based on rated current and on the standard test conditions (see Sub-clauses 8.1.4 and 8.3.1). The temperature coefficient of the resistance of the fuse-link causes an increase in the power loss at a higher rate than the square of the current.

For this reason, the manufacturer provides information about the relation between current and power loss, either in the form of a power loss characteristic or in the form of discrete points.

The power loss characteristic may deviate from the rated value because of installation conditions different from those of the test (see Sub-clause 8.3).

A5.2 *Factors influencing the power loss*

Because of the significant influence on the power losses of the relation between the actual current and the rated current, it may be desirable to use fuse-links of larger current ratings than those determined by repetitive duty and overload. However, the higher current rating does imply a larger value of I^2t. The use of a fuse-link of the highest current rating consistent with a reasonable protection may at the same time reduce the power losses and solve the problems of repetitive duty and overload.

The use of a fuse-link of a higher voltage rating inherently leads to higher values of power losses. If its use is possible in spite of higher values of arc voltage, a reduction of the arcing I^2t will be obtained which may permit the selection of a fuse-link having a higher current rating, resulting in a reduction of the power loss.

Fuse-links having iron parts may show a significant increase of power loss when used at frequencies higher than rated frequency.

A5.3 *Mutual influence*

A very short electrical connection between the fuse-link and the associated semiconductor device provides a significant thermal coupling between the two.

Thus any reduction in the power loss of the fuse-link may improve the current loading of the semiconductor device.

A6. Time/current characteristics

A6.1 *Pre-arcing characteristic*

In the region where the pre-arcing characteristic leaves the adiabatic zone but is still less than 0.1 s to 0.2 s, the deviation from a symmetrical sinusoidal current is often encountered in practice. This may be significant, because the heating is not adiabatic and because the real time (and thereby the cooling) is different from that on which the characteristic is based.

A *pulsed current* as it appears in the arms of rectifiers or invertors cannot be dealt with solely on the basis of its r.m.s. value. In marginal cases, it is necessary to make sure that a single pulse alone cannot damage the fuse element. For instance, if a short-time overload (e.g. below 0.1 s) is considered in accordance with Sub-clause 8.4.3.4, the peak of the actual overload is not the maximum value of the r.m.s. value but the peak of the highest pulse.

Any current of *frequency higher than rated frequency* has practically no influence on the pre-arcing characteristic except in the region mentioned above. For values of prospective current where the virtual pre-arcing time at rated frequency is less than one quarter-cycle, the tendency at higher frequencies is towards pre-arcing times shorter than indicated on the characteristic. For frequencies lower than rated frequency, the effect is the opposite of that mentioned above, but attention is drawn to the fact that the increase in pre-arcing time can be even more significant, particularly towards the higher values of prospective current.

For lower values of prospective current, the only influence of an *asymmetrical current* (a.c. with a transient d.c. component) is to give a slight increase in the r.m.s. value of the current.

In the adiabatic zone, the influence is best considered as an increase or decrease in the rate-of-rise, replacing the actual current by that symmetrical current that has the same (or similar) rate-of-rise during the pre-arcing period.

In the critical zone, where the pre-arcing characteristic leaves the adiabatic zone, a distinction has to be made between an asymmetry beginning with a major loop and one beginning with a minor loop. The major loop will give a decrease in the virtual pre-arcing time, the minor loop will give an increase.

When considering the ability of the fuse-link to withstand an asymmetrical current, the peak of the asymmetry has to be taken into account.

In case of operation with d.c. the pre-arcing characteristic based on a.c. may not be applicable at all, or only partly applicable, depending on the circuit parameters.

If the time constant of the circuit is smaller than the shortest time being considered, the virtual time becomes practically the same as the actual time, and the prospective current is the applied voltage divided by the resistance.

If the circuit contains a significant amount of self-inductance, the adiabatic zone of the pre-arcing characteristic can be used provided the abscissa refers to rate-of-rise instead of prospective current (i.e. the rate-of-rise of the d.c. current is determined as applied voltage divided by the self-inductance). It is further to be assumed that the value of the prospective current (the applied voltage divided by the resistance) is significantly higher (three times or more) than the cut-off current at the rate-of-rise considered.

For the remaining cases of d.c. operation, it is very difficult to draw any significant conclusions about the pre-arcing time to be expected from the normal pre-arcing characteristic based on a.c. and the manufacturer should be consulted. However, the majority of practical cases are covered by the consideration of the rate-of-rise equivalence.

The normal pre-arcing characteristic does not give much information on the behaviour in the case of a *non-sinusoidal current* unless it is either a case where the rate-of-rise is predominant (i.e. for very large currents) or where the current is of such low value that the long time involved permits the use of the r.m.s. value.

A6.2 *Operating characteristic*

For a given prospective current, the time difference between the pre-arcing characteristic and the operating characteristic is the maximum value of the arcing time which is possible under the conditions for which the operating characteristic is drawn. The data presented by the manufacturer are based on a low value of power factor (i.e. below 0.3) and the r.m.s. value of the applied voltage.

The worst case is reached when the instantaneous value of applied voltage is as large as possible both throughout the pre-arcing period and the arcing period. Since this situation seldom occurs, advantage may be taken of this fact.

For the same applied voltage and the same prospective short-circuit current, a *higher frequency* implies a lower value of self-inductance, so the arcing time decreases and within practical limits it is inversely proportional to the frequency.

For the same applied voltage and the same prospective short-circuit current, a *lower frequency* implies a higher value of self-inductance, so the arcing time increases and within practical limits it is inversely proportional to the frequency.

Note. — Because of the longer arcing time and the resulting energy released, it is not ensured that fuse-links are suitable for use at a frequency below rated frequency. The manufacturer should be consulted whenever operating frequency below rated frequency is contemplated.

The influence of *asymmetrical current* has to be taken into account in the selection of the maximum value of the arcing time.

In all cases of *direct current* (see note in Sub-clause A1.1) where the pre-arcing time is judged on the basis of the rate-of-rise (see Sub-clause A6.1) and if the cut-off current is reached at the end of the pre-arcing period, the operating characteristic is also valid provided that the voltage parameter (which is based on r.m.s. values) is so chosen that the applied d.c. voltage is less than the average a.c. voltage (90% of the r.m.s. value). All other cases require special consideration or additional information should be obtained from the manufacturer.

A6.3 *Cut-off characteristic*

In the absence of published information and in the adiabatic zone where cut-off is of interest, the value of cut-off can be estimated from the pre-arcing characteristic by assuming the maximum rate-of-rise during the pre-arcing time for the prospective current considered.

However, if the operating characteristic indicates operating times in excess of two or three times the pre-arcing time, it is likely that the actual cut-off current is higher than estimated.

A7. Breaking capacity

Within the rating, *breaking capacity for non-sinusoidal a.c.* is rarely critical for fuse-links for the protection of semiconductor devices.

For the higher values of voltage (high-voltage fuse-links), the task of breaking small values of current may be a problem, but this problem normally lies outside the range of currents which is of interest here (see Sub-clause 7.4.3).

The breaking capacity is not impaired by frequencies higher than *rated frequency* as long as the maximum value of rate-of-rise of the current for rated frequency is not exceeded. At frequencies lower than rated frequency, the energy released in the fuse-link is larger than at rated frequency. Additional information should be obtained from the manufacturer, which may include a test at the lower frequency, according to Sub-clause 8.5.5.1.

For *breaking capacity on d.c.* (see note in Sub-clause A1.1), the energy released in the fuse-link is in many cases greater than at rated frequency. Often satisfactory operation can be ensured only by using a fuse-link having an a.c. rated voltage appreciably higher than the d.c. supply voltage. Additional information should be obtained from the manufacturer.

A8. Commutation

Short-circuit currents in semiconductor installations normally involve circuits having several arms between which commutation can take place during the operation of the fuse-link. Such commutation can be caused by the cyclic change in the voltage of the a.c. source, by the firing of thyristors or by the arc voltage of another fuse-link.

The commutations influence the operation of the fuse-link by altering the circuit configuration, the circuit constants, and by changing the applied voltage (e.g. by adding an arc voltage).

Another form of unintentional commutation which may seriously affect the duty of the fuse-link is that caused by the appearance of a secondary fault.

APPENDIX B

SURVEY ON INFORMATION TO BE SUPPLIED BY THE MANUFACTURER IN HIS LITERATURE (CATALOGUE) FOR A FUSE DESIGNED FOR THE PROTECTION OF SEMICONDUCTOR DEVICES

(The information shall be given separately for a.c. and, where applicable, for d.c.)

1. Name of the manufacturer (trade mark) (see Sub-clause 6.2).
2. Type or list reference of manufacturer (see Sub-clause 6.2).
3. Rated voltage (see Sub-clause 3.5.1).
4. Rated current (see Sub-clause 3.6).
5. Rated frequency or frequencies (see Sub-clause 5.4).
6. Rated breaking capacity (at rated voltage and at different applied voltages) (see Sub-clauses 3.9 and 8.5).
7. Pre-arcing and operating time/current characteristics (diagrams) and application class (symbol), where applicable (see Sub-clauses 5.6 and 8.4.3.1).
8. Pre-arcing I^2t characteristic (see Sub-clauses 5.8.2.1 and 8.7.2).
9. Operating I^2t characteristic in relation to the voltage with indication of the power factor, or time constant (see Sub-clauses 5.8.2.2 and 8.7.2).
10. Arc voltage at 25%, 50% and 100% of the rated voltage or in the form of a diagram (see Sub-clauses 5.9 and 8.7.3).
11. Cut-off characteristic (see Sub-clauses 5.8.1 and 8.6).
12. Temperature rise at rated current under conventional test conditions and indication of a defined measuring point (see Sub-clauses 7.3 and 8.3.4).
13. Power loss for at least 50% and 100% of the rated current, at fixed points or in the form of a diagram for that range (additional parameters may be 63% and 80%) (see Sub-clauses 7.3 and 8.3.4).
14. Required minimum operating voltage of the indicator (see Sub-clause 8.4.3.2).
15. Permissible current as a function of the ambient temperature (diagram) (see Sub-clause 8.4.3.5).
16. Instructions for mounting, where necessary with respect to the dimensions (sketch).
17. Current-carrying ability under special conditions of mounting (e.g. cross-sectional area of connected conductors. inadequate cooling, additional heat sources, etc.).

Note. — In the case of special conditions, the manufacturer should be consulted.

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